

**CLAIMS:**

1. A CVD single crystal diamond material which shows at least one of the following characteristics, when measured at room temperature (nominally 20°C):
  - i) a high optical homogeneity, with the transmitted wavefront differing from the expected geometrical wavefront during transmission through diamond of a specified thickness of at least 0.5 mm, processed to an appropriate flatness and measured over a specified area of at least 1.3 mm x 1.3 mm, by less than 2 fringes, where 1 fringe corresponds to a difference in optical path length equal to  $\frac{1}{2}$  of the measurement wavelength of 633 nm;
  - ii) a low optical birefringence, indicative of low strain, such that in a sample of a specified thickness of at least 0.5 mm and measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, the modulus of the sine of the phase shift,  $|\sin \delta|$ , for at least 98% of the analysed area of the sample remains in first order ( $\delta$  does not exceed  $\pi/2$ ) and the  $|\sin \delta|$  does not exceed 0.9;
  - iii) a low optical birefringence, indicative of low strain, such that in a sample of a specified thickness of at least 0.5 mm and measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, for 100% of the area analysed, the sample remains in first order ( $\delta$  does not exceed  $\pi/2$ ), and the maximum value of  $\Delta n_{[\text{average}]}$ , the average value of the difference between the refractive index for light polarised parallel to the slow and fast axes averaged over the sample thickness, does not exceed  $1.5 \times 10^{-4}$ ;

- iv) an effective refractive index in a sample of a specified thickness of at least 0.5 mm, measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, which has a value of 2.3964 to within an accuracy of  $\pm 0.002$ ;
- v) a combination of optical properties such that when the diamond material is prepared as a diamond plate in the form of an etalon of a specified thickness of at least 0.5 mm and measured using a laser beam with a wavelength near  $1.55\text{ }\mu\text{m}$  and a nominal diameter of 1.2 mm over a specified area of at least 1.3 mm x 1.3 mm, it exhibits a free spectral range (FSR) which, when measured at different positions over the plate, varies by less than  $5 \times 10^{-3}\text{ cm}^{-1}$ ;
- vi) a combination of optical properties such that when the diamond material is prepared as a diamond plate in the form of a Fabry-Perot solid etalon of a specified thickness of at least 0.5 mm, and measured using a laser beam with a wavelength near  $1.55\text{ }\mu\text{m}$  and a nominal diameter of 1.2 mm over a specified area of at least 1.3 mm x 1.3 mm, and which has no coatings applied to the optically prepared surfaces, it exhibits when measured at different positions over the plate a contrast ratio exceeding 1.5;
- vii) a combination of optical properties such that when the diamond material is prepared as a diamond plate in the form of an etalon of a specified thickness of at least 0.5 mm, and measured using a laser beam with a wavelength near  $1.55\text{ }\mu\text{m}$  and a diameter of 1.2 mm over a specified area of at least 1.3 mm x 1.3 mm, it exhibits an insertion loss not exceeding 3 dB;

- viii) a variation in refractive index over a volume of interest, said volume comprising a layer of a specified thickness of at least 0.5 mm, measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, which is less than 0.002.
2. A CVD single crystal diamond material according to claim 1, wherein the transmitted wavefront differs from the expected geometrical wavefront by less than 0.5 fringes.
  3. A CVD single crystal diamond material according to claim 2, wherein the transmitted wavefront differs from the expected geometrical wavefront by less than 0.2 fringes.
  4. A CVD single crystal diamond material according to any one of the preceding claims, wherein the modulus of the sine of the phase shift,  $|\sin \delta|$ , for at least 98% of the analysed area remains in first order and does not exceed 0.4.
  5. A CVD single crystal diamond material according to any one of the preceding claims, wherein the modulus of the sine of the phase shift,  $|\sin \delta|$ , for 100% of the analysed area remains in first order and where  $\Delta n_{[\text{average}]}$  does not exceed  $5 \times 10^{-5}$ .
  6. A CVD single crystal diamond material according to any one of the preceding claims, which has a value of effective refractive index of 2.3964 to within an accuracy of  $\pm 0.001$ .
  7. A CVD single crystal diamond material according to claim 6, which has a value of effective refractive index of 2.39695 to within an accuracy of  $\pm 0.0005$ .
  8. A CVD single crystal diamond material according to any one of the preceding claims, which exhibits a free spectral range (FSR) which,

when measured at different positions over the material, varies by less than  $2 \times 10^{-3} \text{ cm}^{-1}$ .

9. A CVD single crystal diamond material according to claim 8, wherein the free spectral range varies by less than  $5 \times 10^{-4} \text{ cm}^{-1}$ .
10. A CVD single crystal diamond material according to any one of the preceding claims, which has a variation in refractive index over the volume defined by the specified thickness and the specified area, measured in a manner described herein, which is less than 0.001.
11. A CVD single crystal diamond material according to claim 10, wherein the variation in refractive index is less than 0.0005.
12. A CVD single crystal diamond material according to any one of the preceding claims, which when prepared as a diamond plate in the form of a Fabry-Perot solid etalon exhibits when measured over different positions over the plate of specified thickness and area a contrast ratio exceeding 1.7.
13. A CVD single crystal diamond material according to claim 12, wherein the contrast ratio exceeds 1.8.
14. A CVD single crystal diamond material according to any one of the preceding claims, which when prepared as a diamond plate in the form of a Fabry-Perot solid etalon exhibits, when measured using a laser beam with a wavelength near  $1.55 \text{ }\mu\text{m}$  and a diameter of 1.2 mm over different positions over the plate of specified thickness and area, an insertion loss not exceeding 1 dB.
15. A CVD single crystal diamond material according to claim 14, wherein the insertion loss does not exceed 0.5 dB.

16. A CVD single crystal diamond material which shows at least one of the following characteristics, when measured at room temperature (nominally 20°C):
  - i) a low and uniform optical scatter such that for a sample of a specified thickness of at least 0.4 mm the forward scatter at 1.064  $\mu\text{m}$ , measured in a manner described herein over a specified area of at least 1.3 mm x 1.3 mm, integrated over a solid angle from 3.5° to 87.5° from the transmitted beam, is less than 0.4%;
  - ii) a low and uniform optical absorption such that a sample of a specified thickness of at least 0.5 mm has an optical absorption coefficient at a wavelength of 1.06  $\mu\text{m}$  of less than 0.09  $\text{cm}^{-1}$ ;
  - iii) a low and uniform optical absorption such that a sample of a specified thickness of at least 0.5 mm has an optical absorption coefficient at a wavelength of 10.6  $\mu\text{m}$  of less than 0.04  $\text{cm}^{-1}$ .
17. A CVD single crystal diamond material according to claim 16, wherein the forward scatter at a wavelength of 1.064  $\mu\text{m}$  measured in sample of the specified thickness and area, integrated over a solid angle from 3.5° to 87.5° from the transmitted beam, is less than 0.2%.
18. A CVD single crystal diamond material according to claim 17, which exhibits a forward scatter at 1.064  $\mu\text{m}$  of less than 0.1%.
19. A CVD single crystal diamond material according to any one of claims 16 to 18, wherein the optical absorption coefficient at 1.06  $\mu\text{m}$  is less than 0.05  $\text{cm}^{-1}$ .

20. A CVD single crystal diamond material according to claim 19, wherein the optical absorption coefficient at  $1.06\text{ }\mu\text{m}$  is less than  $0.02\text{ cm}^{-1}$ .
21. A CVD single crystal diamond material according to any one of claims 16 to 20, wherein the optical absorption coefficient at  $10.6\text{ }\mu\text{m}$  is less than  $0.03\text{ cm}^{-1}$ .
22. A CVD single crystal diamond material according to claim 21, wherein the optical absorption coefficient at  $10.6\text{ }\mu\text{m}$  is less than  $0.027\text{ cm}^{-1}$ .
23. A CVD single crystal diamond material which shows at least one of the following characteristics, when measured at room temperature (nominally  $20^{\circ}\text{C}$ ):
  - i) an ability to be processed to show a high surface polish with an  $R_a$  (arithmetic mean of the absolute deviation from the mean line through the profile) measured over a specified area of at least  $1.3\text{ mm} \times 1.3\text{ mm}$  less than  $2\text{ nm}$ ;
  - ii) an ability to be processed to show a high flatness, with a flatness measured using  $633\text{ nm}$  radiation and measured over a specified area of at least  $1.3\text{ mm} \times 1.3\text{ mm}$  which is better than 10 fringes;
  - iii) an ability to be processed to show a high parallelism, with a parallelism measured over a specified area of at least  $1.3\text{ mm} \times 1.3\text{ mm}$  which is better than 1 arc minute.
24. A CVD single crystal diamond material according to claim 23, which can be processed to show a surface polish with an  $R_a$  less than  $1\text{ nm}$ .

25. A CVD single crystal diamond material according to claim 24, which can be processed to show a surface polish with an  $R_a$  less than 0.6 nm.
26. A CVD single crystal diamond material according to any one of claims 23 to 25, which can be processed to show a flatness better than 1 fringe.
27. A CVD single crystal diamond material according to claim 26, which can be processed to show a flatness better than 0.3 fringes.
28. A CVD single crystal diamond material according to any one of claims 23 to 27, which can be processed to show a parallelism better than +/- 30 arc seconds.
29. A CVD single crystal diamond material according to claim 28, which can be processed to show a parallelism better than +/- 15 arc seconds.
30. A CVD single crystal diamond material according to any one of the preceding claims, which shows at least two of the given characteristics.
31. A CVD single crystal diamond material according to any one of claims 1 to 15, which shows at least three of the given characteristics.
32. A CVD single crystal diamond material according to claim 31, which shows at least four of the given characteristics.
33. A CVD single crystal diamond material according to any one of claims 16 to 22, which shows all three of the given characteristics.

34. A CVD single crystal diamond material according to any one of claims 23 to 29, which shows all three of the given characteristics.
35. A CVD single crystal diamond material according to any one of the preceding claims, wherein the specified area of the sample in each of the satisfied characteristics, if given, is at least 2.5 x 2.5 mm.
36. A CVD single crystal diamond material according to claim 35, wherein the specified area of the sample in each of the satisfied characteristics, if given, is at least 4 x 4 mm.
37. A CVD single crystal diamond material according to any one of the preceding claims, wherein the specified thickness of the sample in each of the satisfied characteristics, if given, is at least 0.8 mm.
38. A CVD single crystal diamond material according to claim 37, wherein the specified thickness of the sample in each of the satisfied characteristics, if given, is at least 1.2 mm.
39. A CVD single crystal diamond material which shows a mechanical design strength, measured in a manner described herein, such that at least 70% of samples tested over a batch size of at least 8 will only fail at strength values of at least 2.5 Gpa.
40. A CVD single crystal diamond material according to claim 39, wherein at least 70% of samples tested over a batch size of at least 8 will only fail at strength values of at least 3.0 GPa.
41. A CVD single crystal diamond material according to any one of the preceding claims, having a Raman normalised luminescence intensity of the 575 nm and 637 nm peaks which is less than 40.



42. A CVD single crystal diamond material according to claim 41, having a Raman normalised luminescence intensity of the 575 nm and 637 nm peaks which is less than 10.
43. A CVD single crystal diamond material according to claim 42, having a Raman normalised luminescence intensity of the 575 nm and 637 nm peaks which is less than 3.
44. A CVD single crystal diamond material according to any one of the preceding claims, with a thermal conductivity measured at 20°C which is greater than  $1800 \text{ Wm}^{-1}\text{K}^{-1}$ .
45. A CVD single crystal diamond material according to claim 44, wherein the thermal conductivity measured at 20°C is greater than  $2300 \text{ Wm}^{-1}\text{K}^{-1}$ .
46. A CVD single crystal diamond material according to any one of the preceding claims, in the form of a plate having opposed major faces, which is prepared for use with an average dislocation direction in the plate more than 30° from normal to the major faces.
47. A CVD single crystal diamond material according any one of the preceding claims, which was annealed as part of its preparation.
48. A CVD single crystal diamond material according any one of the preceding claims, which was annealed subsequent to its preparation.
49. A CVD single crystal diamond material according to any one of the preceding claims, which is formed into a mechanical layer or an optical layer or a polished gemstone.
50. A CVD single crystal diamond material according to claim 49, which is formed into a polished gemstone.

51. A CVD single crystal diamond material according to any one of the preceding claims, which exceeds at least one of the following dimensions:
  - a) a lateral dimension of 1 mm,
  - b) a second orthogonal lateral dimension of 1 mm,
  - c) a thickness of 0.1 mm.
52. A CVD single crystal diamond material according to claim 51, wherein a lateral dimension exceeds 5 mm.
53. A CVD single crystal diamond material according to claim 51 or claim 52, wherein the thickness dimension exceeds 0.8 mm.
54. A CVD single crystal diamond material according to any one of claims 51 to 53, which exceeds at least two of the dimensions a to c.
55. A CVD single crystal diamond material according to claim 54, which exceeds all three of the dimensions a to c.
56. A CVD single crystal diamond material according to any one of the preceding claims, for use in, or as, an optical device or element.
57. A CVD single crystal diamond material according to any one of the preceding claims, which contains less than  $5 \times 10^{17}$  atoms/cm<sup>3</sup> N in single substitutional form as measured by EPR.
58. A CVD single crystal diamond material according to claim 57, which contains less than  $2 \times 10^{17}$  atoms/cm<sup>3</sup> N in single substitutional form as measured by EPR.

59. A CVD single crystal diamond material according to any one of the preceding claims, which contains more than  $3 \times 10^{15}$  atoms/cm<sup>3</sup> N in single substitutional form as measured by EPR.
60. A CVD single crystal diamond material according to claim 59, which contains more than  $1 \times 10^{16}$  atoms/cm<sup>3</sup> N in single substitutional form as measured by EPR.
61. A CVD single crystal diamond material according to claim 60, which contains more than  $5 \times 10^{16}$  atoms/cm<sup>3</sup> N in single substitutional form as measured by EPR.
62. A method of producing a CVD diamond material suitable for optical applications includes the steps of providing a substrate substantially free of crystal defects, providing a source gas, dissociating the source gas to produce a synthesis atmosphere which contains 300 ppb to 5 ppm nitrogen, calculated as molecular nitrogen, and allowing homoepitaxial diamond growth on the surface which is substantially free of crystal defects.
63. A method according to claim 62, wherein the synthesis atmosphere contains more than 500 ppb nitrogen, calculated as molecular nitrogen.
64. A method according to claim 63, wherein the synthesis atmosphere contains more than 800 ppb nitrogen, calculated as molecular nitrogen.
65. A method according to any one of claims 62 to 64, wherein the synthesis atmosphere contains no more than 2 ppm nitrogen, calculated as molecular nitrogen.

- 66. A method according to claim 65, wherein the synthesis atmosphere contains no more than 1.5 ppm nitrogen, calculated as molecular nitrogen.
- 67. A method according to claim 62, wherein the level of nitrogen is selected to be sufficient to prevent or reduce local strain generating defects whilst being low enough to prevent or reduce deleterious absorptions and crystal quality degradation.
- 68. A method according to any one of claims 62 to 67, wherein the density of defects is such that surface etch features related to defects is below  $5 \times 10^3/\text{mm}^2$ .
- 69. A method according to claim 68, wherein the density of defects is such that surface etch features related to defects is below  $10^2/\text{mm}^2$ .
- 70. A method according to any one of claims 62 to 69, wherein the surface of the diamond substrate on which CVD diamond growth occurs is the {100} surface.
- 71. A method according to any one of claims 62 to 70, wherein the level of nitrogen is controlled with an error of less than 300 ppb (as a molecular fraction of the total gas volume) or 10% of the target value in the gas phase, whichever is the larger.
- 72. A method according to claim 71, wherein the level of nitrogen is controlled with an error of less than 100 ppb (as a molecular fraction of the total gas volume) or 3% of the target value in the gas phase, whichever is the larger.
- 73. A method according to claim 72, wherein the level of nitrogen is controlled with an error of less than 50 ppb (as a molecular fraction of the total gas volume) or 2% of the target value in the gas phase, whichever is the larger.

- 74. A method according to any one of claims 62 to 73, wherein the properties of the CVD single crystal diamond material produced are further enhanced by annealing the diamond material.
- 75. A CVD single crystal diamond material produced by a method according to any one of claims 62 to 74.
- 76. An etalon produced from a CVD single crystal diamond material according to any one of claims 1 to 61 and 75.
- 77. An etalon according to claim 76, which is a Fabry-Perot etalon or a Gires-Tournois etalon.